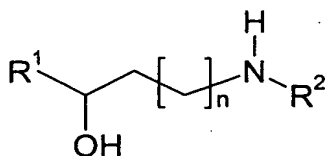


PROCESS FOR THE ENANTIOSELECTIVE HYDROGENATION OF AMINO ALCOHOLS

The invention relates to a process for the enantioselective preparation of amino alcohols of the formula I



in which

R^1 denotes a saturated, unsaturated or aromatic carbocyclic or heterocyclic radical which is unsubstituted or mono- or polysubstituted by R^3 and/or R^4 ,

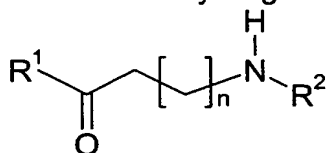
R^2 denotes alkyl having 1-20 C atoms or H,

R^3, R^4 each, independently of one another, denote H, alkyl or alkoxy having 1-20 C atoms, aryl, aryloxy or COOR^2 , F, Cl, Br, OH, CN, NO_2 , $\text{N(R}^2)_2$ or NHCOR_2

and

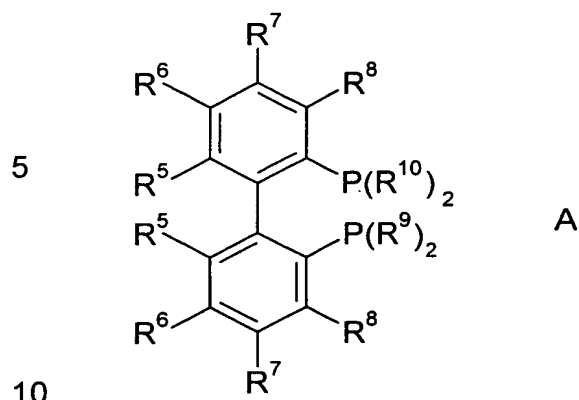
n denotes 0, 1, 2 or 3,

by enantioselective hydrogenation of amino ketones of the formula II



in which

R^1, R^2 and n have the meaning indicated above, in the presence of a non-racemic catalyst, characterised in that the catalyst is a transition-metal complex in which the transition metal is complexed to a chiral diphosphine ligand A



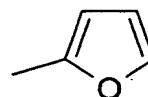
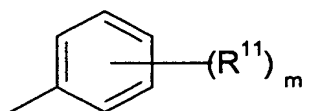
in which

R^5 , R^6 , R^7 and R^8

each, independently of one another, denote H, alkyl or alkoxy having 1-20 C atoms, aryl, aryloxy or F, Cl, Br, $N(R^2)_2$ or $NHCOR_2$

each, independently of one another, denote

R^9 and R^{10}



or cyclohexyl

R^{11}

denotes H, alkyl or alkoxy having 1-20 C atoms, aryl, aryloxy or SO_3Na , $COOR^{12}$, F, Cl, $N(R^{12})_2$ or $NHCOR^{12}$,

R^{12}

denotes alkyl having 1-20 C atoms or H

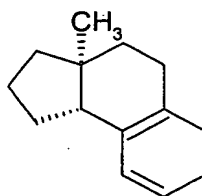
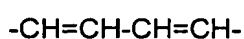
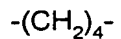
and

m

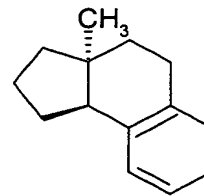
denotes 0, 1, 2 or 3,

where R^5 and R^6 , R^6 and R^7 and R^7 and R^8 together can also have the meaning

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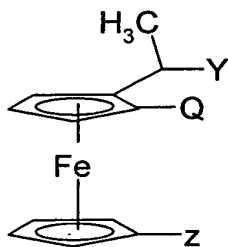


or



or B

10



B

15

in which

Y denotes OH, P(cyclohexyl)₂, P(3,5-dimethylphenyl)₂ or P(C(CH₃)₃)₂,

Z denotes H or P(phenyl)₂,

Q denotes PPh₂, P(cyclohexyl)₂, P[3,5-bis(trifluoromethyl)phenyl]₂,

20

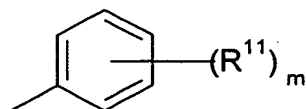
P(4-methoxy-3,5-dimethylphenyl)₂ or P(C(CH₃)₃)₂

and

Ph denotes phenyl, o-, m- or p-methylphenyl or dimethylphenyl.

In the compounds of the formula A, R^9 and R^{10} preferably denoted

25

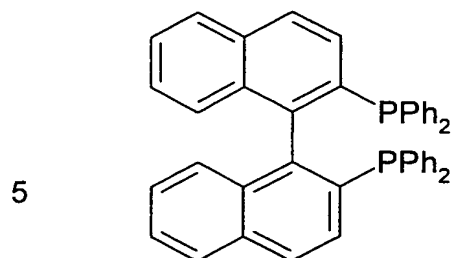


or cyclohexyl.

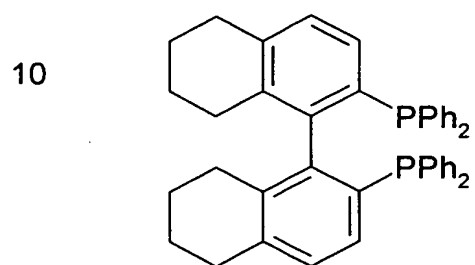
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Particular preference is given to compounds of the formula A1

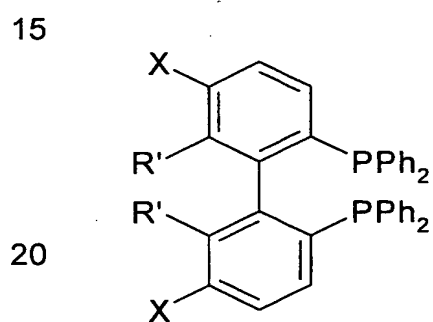
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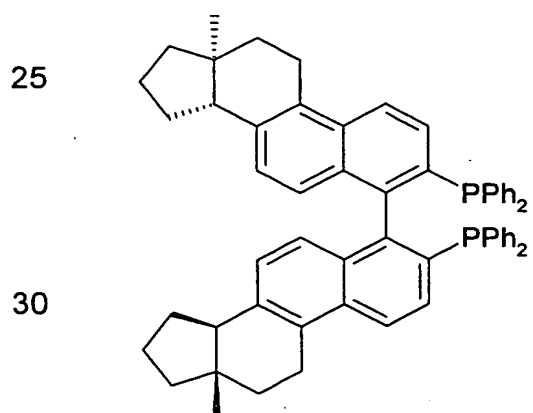
A1



A2

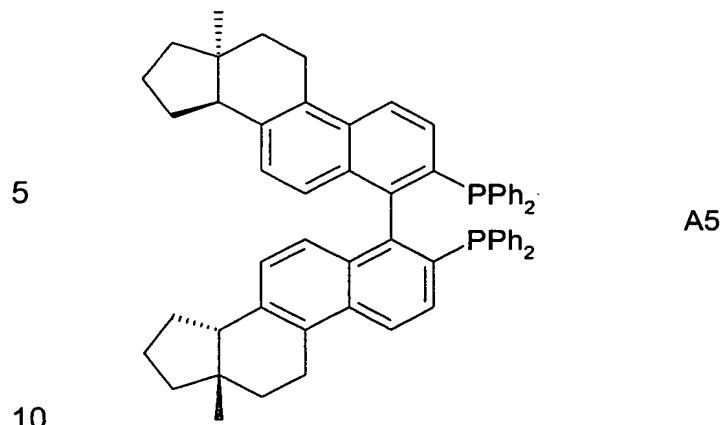


A3



A4

35



in which Ph has the meaning indicated above, and X denotes H, alkyl, O(alkyl), Cl, or F and R' denotes alkyl O(alkyl) or F. Particular preference is given to compounds of the formula A3 in which Ph denotes phenyl, X denotes H and R' denotes OCH₃.

Preferred compounds of the formula A are symmetrical.

The compounds of the formula II are preferably employed as acid-addition salts, where, in particular, the acid-addition salts of strong acids, such as, for example, hydrohalic acid, methyl-, p-toluene- or benzenesulfonic acid, perchloric, sulfuric or phosphoric acid, but also acetic acid, formic acid or propanoic acid, are suitable. Particular preference is given to acid-addition salts with sulfuric acid or the hydrochlorides of the compounds of the formula II. Use of the acid-addition salts of the compounds of the formula II gives the acid-addition salts of the compounds of the formula I, from which the free bases can be liberated by addition of a strong base, such as alkali metal carbonate or hydroxide.

The invention therefore relates, in particular, to a process for the preparation of the optically active forms, and the salts, hydrates and solvates, for example alcoholates, of the compounds of the formula I, in particular the compounds of the formula I in which n denotes 1.

The invention preferably facilitates the synthesis of optically active, aryl-substituted 3-monoalkylaminopropanols which are suitable as precursors in the preparation of antidepressants.

In particular, it opens up the possibility of obtaining enantiomerically pure or enantiomerically enriched (S)-3-methylamino-1-(2-thienyl)-1-propanol in a simple manner starting from 3-methylamino-1-(2-thienyl)-1-propanone. Likewise, enantiomerically pure or enantiomerically enriched (S)-3-methylamino-1-phenyl-1-propanol can be obtained in a simple manner starting from 3-methylamino-1-phenyl-1-propanone.

Cleavage of the racemic alcohol enables the desired enantiomer of 3-methylamino-1-(2-thienyl)-1-propanol to be obtained naturally in a maximum yield of 50% (for example analogously to Chirality 2000, 12, 26 or EP 650965).

J. Labelled Compd. Radiopharm. 1995, 36(3), 213 and Tetrahedron Lett. 1990, 31(49), 7101, describe the asymmetric synthesis of (S)-3-methylamino-1-(2-thienyl)-1-propanol. However, both synthetic routes require further transformations or the stoichiometric use of a chiral reagent. By contrast, the process according to the invention described here results in the desired enantiomer of the end product with high selectivity and yield without further transformations.

In general, the homogeneous hydrogenation of 3-aminoketones is regarded as problematical since in the majority of cases elimination products are obtained instead of the desired alcohol (J. Organomet. Chem. 1982, 232, C17 or Synlett, 1997, 1306). In the process according to the invention, this elimination proves to be unimportant (proportion of elimination product less than 2%).

Comparable processes for the preparation of 3-aminoalcohols are described in Synlett 1991, 689, but similar compounds are reduced to the corresponding alcohols with significantly worse enantioselectivities.

Although the homogeneous ruthenium catalyst used in Org. Lett. 2000, 2(12), 1749, gives the alcohol in the hydrogenation of the 3-dimethylaminoketone with similarly good selectivities, a complex demethylation to be carried out subsequently is necessary to obtain the desired (S)-3-methylamino-1-(2-thienyl)-1-propanol or (S)-3-methylamino-1-phenyl-1-propanol, in contrast to the process according to the invention. The formation of toxic and carcinogenic methyl chloride proves to be particularly disadvantageous here.

5 The invention therefore had the object of finding a process for the preparation of compounds which can be used, in particular, as intermediates in the synthesis of medicaments and which does not have the above-mentioned disadvantages.

10 It has been found that the compounds of the formula I and salts thereof which are important intermediates for the preparation of medicaments, in particular of those which exhibit, for example, actions on the central nervous system, can be obtained by enantioselective hydrogenation of compounds of the formula II in the presence of a chiral, non-racemic transition-metal catalyst.

15 Above and below, the radicals R^1 , R^2 , R^3 , R^4 , R^5 , R^6 , R^7 , R^8 , R^9 , R^{10} , R^{11} and R^{12} , Q, Y and Z and the index m and n have the meanings indicated for the formulae I, II, A and B, unless expressly stated otherwise. If they occur more than once within a formula, the meanings of the individual radicals are independent of one another.

20 In the above formulae, alkyl has 1 to 20 C atoms, preferably 1 to 6, in particular 1, 2, 3 or 4 C atoms. Alkyl preferably denotes methyl or ethyl, furthermore propyl, isopropyl, furthermore also butyl, isobutyl, sec-butyl or tert-butyl.

25 R^1 is preferably an aromatic carbocyclic or heterocyclic radical which is unsubstituted or substituted by R^3 and/or R^4 . This radical may be mono- or polycyclic and is preferably mono- or bicyclic, but in particular monocyclic. R^1 is particularly preferably unsubstituted.

30 If R^1 denotes a carbocyclic radical, this radical is preferably, for example, phenyl, o-, m- or p-tolyl, o-, m- or p-hydroxyphenyl, o-, m- or p-methoxyphenyl, o-, m- or p-fluorophenyl.

35 If R^1 denotes a heterocyclic radical, 2- or 3-furyl, 2- or 3-thienyl, 1-, 2- or 3-pyrrolyl, 1-, 2, 4- or 5-imidazolyl, 1-, 3-, 4- or 5-pyrazolyl, 2-, 4- or 5-oxazolyl, 3-, 4- or 5-isoxazolyl, 2-, 4- or 5-thiazolyl, 3-, 4- or 5-isothiazolyl, 2-, 3- or 4-pyridyl, 2-, 4-, 5- or 6-pyrimidinyl, furthermore preferably 1,2,3-tri-

azol-1-, -4- or -5-yl, 1,2,4-triazol-1-, -3- or 5-yl, 1- or 5-tetrazolyl, 1,2,3-oxadiazol-4- or -5-yl, 1,2,4-oxadiazol-3- or -5-yl, 1,3,4-thiadiazol-2- or -5-yl, 1,2,4-thiadiazol-3- or -5-yl, 1,2,3-thiadiazol-4- or -5-yl, 3- or 4-pyridazinyl, pyrazinyl, 1-, 2-, 3-, 4-, 5-, 6- or 7-indolyl, 4- or 5-isoindolyl, 1-, 2-, 4- or 5-benzimidazolyl, 1-, 3-, 4-, 5-, 6- or 7-benzopyrazolyl, 2-, 4-, 5-, 6- or 7-benzoxazolyl, 3-, 4-, 5-, 6- or 7- benzisoxazolyl, 2-, 4-, 5-, 6- or 7-benzothiazolyl, 2-, 4-, 5-, 6- or 7-benzisothiazolyl, 4-, 5-, 6- or 7-benz-2,1,3-oxadiazolyl, 2-, 3-, 4-, 5-, 6-, 7- or 8-quinolyl, 1-, 3-, 4-, 5-, 6-, 7- or 8-isoquinolyl, 3-, 4-, 5-, 6-, 7- or 8-cinnolyl, 2-, 4-, 5-, 6-, 7- or 8-quinazolinyl, 5- or 6-quinoxalyl, 2-, 3-, 5-, 6-, 7- or 8-2H-benzo[1,4]oxazinyl, further preferably 1,3-benzodioxol-5-yl, 1,4-benzodioxan-6-yl, 2,1,3-benzothiadiazol-4- or -5-yl or 2,1,3-benzoxadiazol-5-yl, for example, are preferably suitable.

The heterocyclic radicals may also be partially or fully hydrogenated. The heterocyclic radical used can thus also be, for example, 2,3-dihydro-2-, -3-, -4- or -5-furyl, 2,5-dihydro-2-, -3-, -4- or 5-furyl, tetrahydro-2- or -3-furyl, 1,3-dioxolan-4-yl, tetrahydro-2- or -3-thienyl, 2,3-dihydro-1-, -2-, -3-, -4- or -5-pyrrolyl, 2,5-dihydro-1-, -2-, -3-, -4- or -5-pyrrolyl, 1-, 2- or 3-pyrrolidinyl, tetrahydro-1-, -2- or -4-imidazolyl, 2,3-dihydro-1-, -2-, -3-, -4- or -5-pyrazolyl, tetrahydro-1-, -3- or -4-pyrazolyl, 1,4-dihydro-1-, -2-, -3- or -4-pyridyl, 1,2,3,4-tetrahydro-1-, -2-, -3-, -4-, -5- or -6-pyridyl, 1-, 2-, 3- or 4-piperidinyl, 2-, 3- or 4-morpholinyl, tetrahydro-2-, -3- or -4-pyranyl, 1,4-dioxanyl, 1,3-dioxan-2-, -4- or -5-yl, hexahydro-1-, -3- or -4-pyridazinyl, hexahydro-1-, -2-, -4- or -5-pyrimidinyl, 1-, 2- or 3-piperazinyl, 1,2,3,4-tetrahydro-1-, -2-, -3-, -4-, -5-, -6-, -7- or -8-quinolyl, 1,2,3,4-tetrahydro-1-, -2-, -3-, -4-, -5-, -6-, -7- or -8-isoquinolyl, 2-, 3-, 5-, 6-, 7- or 8-3,4-dihydro-2H-benzo[1,4]oxazinyl, further preferably 2,3-methylenedioxyphenyl, 3,4-methylenedioxyphenyl, 2,3-ethylenedioxyphenyl, 3,4-ethylenedioxyphenyl, 3,4-(difluoromethylenedioxy)phenyl, 2,3-dihydrobenzofuran-5- or 6-yl, 2,3-(2-oxomethylenedioxy)phenyl or also 3,4-dihydro-2H-1,5-benzodioxepin-6- or -7-yl, furthermore preferably 2,3-dihydrobenzofuranyl or 2,3-dihydro-2-oxo-furanyl.

The said heterocyclic radicals may additionally be substituted by R^3 and/or R^4 .

R¹ particularly preferably denotes phenyl or 2-thienyl.

5 R² preferably denotes methyl, ethyl, n-propyl or isopropyl, but in particular methyl.

R³ and R⁴, independently of one another, denote H, methyl, in particular H.

10 R⁵ and R⁶ preferably denote H, alkyl, O-alkyl, Cl or F.

Preference is furthermore given to compounds of the formula A in which R⁵ and R⁶ together form a ring system.

15 R⁷ and R⁸ preferably denote H.

R¹¹ is preferably H or methyl, in particular methyl.

R¹² is preferably methyl or ethyl.

20 n is preferably 0 or 1, in particular 1.

m is preferably 1.

25 Aryloxy preferably denotes, for example, phenoxy, o-, m- or p-tolyloxy, o-, m- or p-hydroxyphenoxy, o-, m- or p-methoxyphenoxy, o-, m- or p-fluorophenoxy.

30 Aryl preferably denotes, for example, phenyl, o-, m- or p-tolyl, o-, m- or p-hydroxyphenyl, o-, m- or p-methoxyphenyl, o-, m- or p-fluorophenyl.

Preference is given to the use of the chiral ligands of the formula A.

35 Ph denotes phenyl, 2-, 3- or 4-methylphenyl, 2,3-, 2,4-, 2,5-, 2,6-, 3,4- or 3,5-dimethylphenyl.

Ph preferably denotes phenyl, 4-tolyl or 3,5-dimethylphenyl, where 4-tolyl is particularly preferred.

Y preferably denotes $P(C(CH_3)_3)_2$.

Z preferably denotes H.

Q preferably denotes $P(phenyl)_2$.

5

Preference is given to chiral ligands of the formula B in which Z has the meaning H and Y $P(C(CH_3)_3)_2$. Preference is furthermore given to ligands of the formula B in which Z has the meaning $P(phenyl)_2$ and Y has the meaning OH.

10

Preference is furthermore given to ligands of the formula B with the following combinations of the radicals Q and Y:

Q = PPh_2 ; Y = $P(cyclohexyl)_2$

Q = PPh_2 ; Y = $P(tert-butyl)_2$

15

Q = $P(cyclohexyl)_2$; Y = $P(cyclohexyl)_2$

Q = PPh_2 ; Y = $P(3,5-dimethylphenyl)_2$

Q = $P[3,5-bis(trifluoromethyl)phenyl]_2$; Y = $P(cyclohexyl)_2$

Q = $P(4-methoxy-3,5-dimethylphenyl)_2$; Y = $P(3,5-dimethylphenyl)_2$

Q = $P[3,5-bis(trifluoromethyl)phenyl]_2$; Y = $P(3,5-dimethylphenyl)_2$

20

Q = $P(cyclohexyl)_2$; Y = $P(tert-butyl)_2$

Q = $P(tert-butyl)_2$; Y = $P(3,5-dimethylphenyl)_2$

The process according to the invention is particularly suitable for the preparation of the alcohols (S)-3-methylamino-1-phenyl-1-propanol or (S)-3-methylamino-1-(2-thienyl)-1-propanol, which can advantageously be converted further into the active ingredients duloxetine, fluoxetine, tomoxetine and LY227942.

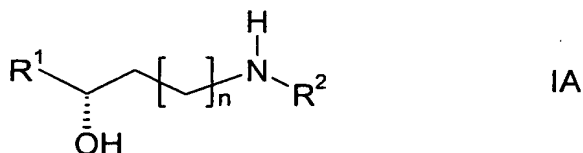
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The compounds of the formula I have one or more chiral centres and can therefore occur in various stereoisomeric forms. The formula I encompasses all these forms.

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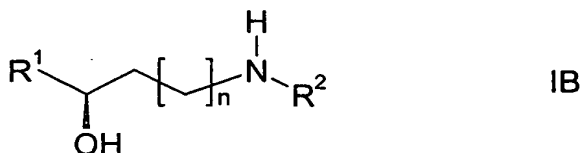
The term "enantioselective preparation" defines a process which generally produces, as reaction product, a mixture comprising a compound of the formula IA

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5

and a compound of the formula IB



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in which R^1 , R^2 and n have the meaning indicated above, where this mixture is not racemic and preferably only still contains traces of the undesired enantiomer, depending on the chirality and selectivity of the catalyst used. In this case, reference is made above and below approximately to a process for the preparation of the enantiomerically pure compounds of the formula IA or IB. Processes for the preparation of the enantiomerically pure compounds of the formula IA are preferred.

20

In particular, it has been found that the compounds of the formula II can be hydrogenated using the enantiomerically pure rhodium-phosphine complexes containing the phosphines A or B to give enantiomerically pure or enantiomerically enriched compounds of the formula I.

25

The invention also relates to a process for the preparation of the compounds of the formula I, characterised in that the chiral, non-racemic catalyst is an enantiomerically enriched transition-metal complex containing one or more metals or salts thereof selected from the group consisting of rhodium, iridium, ruthenium and palladium. Particular preference is given to the use of transition-metal complexes containing rhodium or rhodium salts.

30

Particular preference is given to transition-metal salts containing sulfate, chloride, methanesulfonate, toluenesulfonate, hexachloroantimonate, hexafluoroantimonate or trifluoromethanesulfonate as anion.

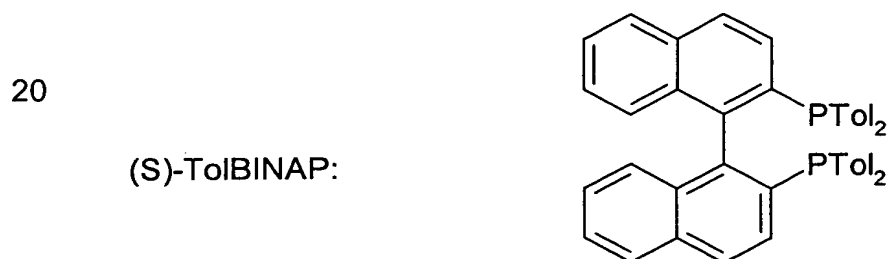
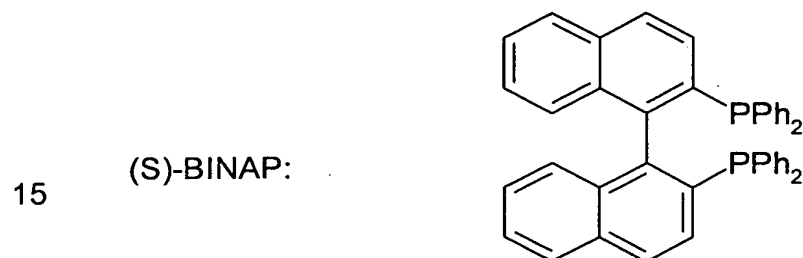
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Preference is given to the use of enantiomerically pure transition-metal complexes.

5 The term "enantiomerically pure" above and below denotes an enantiomeric purity of >90% ee, preferably > 92% ee and in particular >99% ee.

Depending on the choice of the (R)- or (S)-enantiomer of the ligand in the catalyst, the (R)- or (S)-enantiomer is obtained in excess.

10 Particular preference is given to the ligands:



25 in which Tol denotes 4-methylphenyl. (S)-ToIBINAP is particularly preferred.

The starting compound used for the preparation of the chiral complexes is preferably compounds such as, for example, [Rh(COD)₂]OTf (cyclooctadienylrhodium triflate), [Rh(COD)Cl]₂, [Rh(COD)₂]BF₄, [Ir(COD)Cl]₂, [Ir(COD)₂]BF₄, [Rh(NBD)Cl]₂ (norbornadienylrhodium chloride), [Rh(ethylene)₂Cl]₂, RhX₃ · nH₂O, in which X denotes Cl, Br or I or [Ru(COD)Cl]₂. [Rh(COD)Cl]₂ is preferred.

35 Further preferred rhodium complexes contain one of the following anions

Cl, Br, I, PF₆, [PF₃(C₂F₅)₃], SbF₆, BF₄, ClO₄, BPh₄, tetra(3,5-bis-trifluoromethylphenyl)borate, OOCCH₃, OOCCH₂CH₃, trifluoromethanesulfonate, p-toluenesulfonate, methanesulfonate

and

diethyl ether or one of the following unsaturated compounds:

1,5-cyclooctadiene, cyclooctene, 2,5-norbornadiene, norbornene.

The compounds of the formula II and also the starting materials for their preparation are, in addition, prepared by methods known per se, as described in the literature (for example in the standard works, such as Houben-Weyl, Methoden der organischen Chemie [Methods of Organic Chemistry], Georg-Thieme-Verlag, Stuttgart), to be precise under reaction conditions which are known and suitable for the said reactions. Use can also be made here of variants known per se which are not mentioned here in greater detail.

If desired, the starting materials can also be formed in situ by not isolating them from the reaction mixture, but instead immediately converting them further into the compounds of the formula I.

Suitable solvents are, for example, water, hydrocarbons, such as hexane, petroleum ether, benzene, toluene or xylene; chlorinated hydrocarbons, such as trichloroethylene, 1,2-dichloroethane, tetrachloromethane, chloroform or dichloromethane; alcohols, such as methanol, ethanol, isopropanol, n-propanol, n-butanol or tert-butanol; ethers, such as diethyl ether, diisopropyl ether, tetrahydrofuran (THF) or dioxane; glycol ethers, such as PEG, ethylene glycol monomethyl or monoethyl ether, ethylene glycol dimethyl ether (diglyme); ketones, such as acetone, methyl ethyl ketone or butanone; amides, such as acetamide, dimethylacetamide or dimethylformamide (DMF); nitriles, such as acetonitrile; sulfoxides, such as dimethyl sulfoxide (DMSO); carbon disulfide; nitro compounds, such as

nitromethane or nitrobenzene; esters, such as methyl acetate or ethyl acetate, if desired also mixtures of the said solvents with one another or mixtures with water. Particular preference is given to mixtures of hydrocarbons with alcohols, in particular mixtures of methanol with toluene.

5

Particular preference is given to a process in which the hydrogenation is carried out in the presence of one or more alcohols, in particular methanol.

10

The reaction time of the enantioselective hydrogenation is between a few minutes and 14 days, depending on the conditions used, the reaction temperature is between 0 and 200°C, normally between 10 and 150°C, preferably between 20 and 130°C and in particular between 20 and 70°C.

15

The catalyst/substrate ratio is usually between 1:10,000 and 1:20, preferably between 1:5000 and 1:50, particularly preferably 1:2000 to 1:100. The reaction time is then, for example, between 0.1 and 30 preferably between 3 and 20 hours. The hydrogenation is preferably carried out under a hydrogen pressure of 1-250 bar, preferably at 3-210 bar, in particular between 120 and 200 bar.

20

The reactions are preferably carried out under oxygen-free reaction conditions.

25

For purification of the compounds of the formula I, it may be advantageous to follow the hydrogenation with crystallisation. In this case, in particular in the case where R¹ denotes 2-thienyl and R² denotes methyl, particularly high enantiomeric excesses are achieved without significant reductions in yield having to be accepted.

30

The invention furthermore relates to the use of the compounds of the formula I as intermediates for the synthesis of medicaments.

Corresponding medicaments are mentioned, for example, in J. Labelled Compd. Radiopharm. 1995, 36(3), 213.

35

The invention furthermore relates to the use of the compounds of the formula I as intermediates for the synthesis of medicaments which exhibit actions on the central nervous system.

Above and below, all temperatures are indicated in °C and pressures in bar.

5

Examples:

All reactions were carried out under inert conditions (i.e. anhydrous and oxygen-free reaction conditions).

10

1. Preparation of the catalyst/substrate solution:

Example 1:

51.4 mg of $[\text{Rh}(\text{COD})\text{Cl}]_2$ were dissolved in 5 ml of the solvent mixture toluene, and a solution consisting of 5 ml of toluene and equivalents 1.1 of (S)-(-)-2,2'-bis(di-p-tolylphosphino)-1,1'-binaphthyl was added.

15

2. Sampling and analysis

The enantiomeric excess of the hydrogenation product was determined on chiral HPLC phase.

20

Example 2:

5.3 mg of bis(1,5-cyclooctadienyl)dirhodium(I) dichloride and 17.2 mg of (S)-(-)-2,2'-bis(di-p-tolylphosphino)-1,1'-binaphthyl are added to 8.23 g of 3-methylamino-1-(2-thienyl)-1-propanone in a steel autoclave, and 50 ml of methanol and 50 ml of toluene are added to this mixture. After the reactor has been sealed, the reactor is freed from oxygen by flushing a number of times with nitrogen and subsequently hydrogen. The reactor is charged with 55 bar of hydrogen and warmed to 50°C. The course of the reaction is monitored through the pressure drop in the autoclave. The reaction is complete after 15 hours.

25

30

The desired alcohol is obtained with an enantiomeric excess of 92.8% ee.

Example 3:

The oily residue obtained in accordance with Example 2 is taken up in 300 ml of water, extracted 3 times with 250 ml of dichloromethane each time, and the organic phase is discarded. 250 ml of dichloromethane are subsequently again added to the aqueous phase, the pH is adjusted to 14

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using 41.0 g of 32% sodium hydroxide solution, and the phases are separated. The organic phase is freed from the solvent. The oil obtained is dissolved in 320 g of an MTB ether/toluene mixture at 55°C, 2.5 g of activated carbon are added, and the mixture is filtered while hot. After the
5 virtually colourless solution has been slowly cooled to room temperature, the reaction solution is seeded with a few seed crystals and cooled at -15°C for 16 h. The deposited crystals are filtered off with suction and dried in vacuo, giving the desired (S)-N-methyl-3-hydroxy-3(2-thienyl)propanamine with an ee value of >99%.
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Example 4:

18.93 g (92 mmol) of 3-methylamino-1-(2-thienyl)-1-propanone are weighed out into a steel autoclave, 90 ml of methanol are added, and the mixture is inertised by injecting 7 bar of nitrogen 3 times followed by de-
15 compression. 10.8 mg (0.022 mmol) of bis(1,5-cyclooctadienyl)dirhodium(I) dichloride and 32.5 mg (0.051 mmol) of (S)-BINAP are weighed out into a Schlenk tube and dissolved in 18 ml of toluene under argon. This solution is transferred into the autoclave using a cannula in a counterstream of nitrogen. The autoclave is then flushed by charging 3 times with 10 bar of
20 hydrogen each time followed by decompression.

The autoclave is heated to 50°C, and the internal pressure is adjusted to 120 bar of hydrogen after this temperature has been reached. After 7 hours, the uptake of hydrogen ceases, the reaction is terminated, and the reaction solution is analysed.

25 Conversion to the product: 98%; enantiomeric excess in the product: 94%.

Example 5:

495 g (2.4 mol) of 3-methylamino-1-(2-thienyl)-1-propanone are weighed out into a steel autoclave, 2.3 l of methanol and 0.4 l of toluene are added,
30 and the mixture is inertised by injecting 7 bar of nitrogen 3 times followed by decompression. 297 mg (0.60 mmol) of bis(1,5-cyclooctadienyl)-dirhodium(I) dichloride and 900 mg (1.325 mmol) of (S)-ToIBINAP are weighed out into a Schlenk flask and dissolved in 80 ml of toluene under argon. This solution is transferred into the autoclave using a cannula in a
35 counterstream of nitrogen. The autoclave is then flushed by charging 3 times with 10 bar of hydrogen each time followed by decompression.

The autoclave is heated to 50°C, and the internal pressure is adjusted to 60 bar of hydrogen after this temperature has been reached. After 8 hours, the uptake of hydrogen ceases, the reaction is terminated, and the reaction solution is analysed.

5 Conversion to the product: >99%; enantiomeric excess in the product: 92%.

Example 6:

10 16.46 g (80 mmol) of 3-methylamino-1-(2-thienyl)-1-propanone are weighed out into a steel autoclave, 75 ml of methanol are added, and the mixture is inertised by injecting 7 bar of nitrogen 3 times followed by decompression. 5.2 mg (0.011 mmol) of bis(1,5-cyclooctadienyl)-dirhodium(I) dichloride and 15.2 mg (0.022 mmol) of (S)-TolBINAP are
15 weighed out into a Schlenk tube and dissolved in 15 ml of toluene under argon. This solution is transferred into the autoclave using a cannula in a counterstream of nitrogen. The autoclave is then flushed by charging 3 times with 10 bar of hydrogen each time followed by decompression. The autoclave is heated to 50°C, and the internal pressure is adjusted to
20 120 bar of hydrogen after this temperature has been reached. After 11 hours, the uptake of hydrogen ceases, the reaction is terminated, and the reaction solution is analysed.

Conversion to the product: >99%; enantiomeric excess in the product: 92%.

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